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Analysis and Interpretation of Polygraphic Sleep Recordings of Overnight Sleep and Two hour Recuperative Nap

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Abstract

Sixty four healthy volunteers, aged 20 to 36 years, were grouped in teams of four. Eight teams were military (24 males and 8 females) and 8 were civilian (17 males and 15 females). The Team and Individual Threat Assessment Network (TITAN), was used in this experiment to investigate team decision making. Fifty six subjects were randomly assigned either to a feedback or no feedback condition and 8 military subjects did a control condition (solo condition). Participants were equipped for continuous ambulatory recording of EEG, EOG and EMG and completed 14 x 2-hour experimental blocks during the sleep deprivation portion of the experiment. Subjects completed two additional 25-min team task sessions (before and after the nap) to study the effects of sleep inertia on team performance. A two-hour nap was scheduled between 1330 and 1530 hrs after 30.5 hrs of sleep loss. TITAN performance showed that whether subjects were performing in teams or individually they suffered from significant sleep inertia impairments immediately upon awakening from the nap. However, teams were able to improve their performance with time awake whereas individual performance was still affected by sleep inertia by the end of the 24 min session. Finally, even in the presence of feedback, subjective ratings of accuracy and the number of targets processed clearly showed that half of the subjects were not aware of significant performance impairments upon awakening from the nap. In conclusion, upon awakening from a recuperative nap, and in the presence or absence of external feedback, both accuracy and speed of performance is impaired by sleep inertia and only half of the subjects were able to correctly predict these performance impairments.

Résumé

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Executive Summary

One of the main limitations of using naps to reduce sleepiness and improve the performance of workers in around-the-clock operational settings is sleep inertia. To our knowledge, there have been no studies evaluating performance impairment associated with sleep inertia in individuals working in teams . Sixty four healthy volunteers, aged 20 to 36 years, were grouped in teams of four. Eight teams were military (24 males and 8 females) and 8 were civilian (17 males and 15 females). Fifty six subjects were randomly assigned either to a feedbak or no feedback condition and 8 military subjects did a control condition (solo condition). Participants were equipped for continuous ambulatory recording of EEG, EOG and EMG and completed 14 x 2-hour experimental blocks during the sleep deprivation portion of the experiment. Each 2-hour block comprised: a) 25-min team task, b) 25-min individual cognitive task, c) 25-min team task, d) 25-min psychomotor test battery, e) 20-min break. Subjects completed two additional 25-min team task sessions (one prior to the nap and one immediately upon awakening from the nap) to study the effects of sleep inertia on team performance. The Team and Individual Threat Assessment Network (TITAN), was used in this experiment to investigate team decision making. A two-hour nap was scheduled between 1330 and 1530 hrs after 30.5 hrs of sleep loss. Analyses of Titan performance showed that whether subjects were performing in teams or individually they suffered from significant sleep inertia impairments immediately upon awakening from the nap. Sleep inertia had more impact on performance of individuals than teams. Essentially, teams were able to improve their performance with time awake whereas individual performance was still affected by sleep inertia by the end of the 24 min session. When looking at the impact of feedback on performance, the results showed that Military and Civilian were affected differently. Even though all leaders and subordinates took longer to process targets immediately upon awakening because of sleep inertia effects, Military subjects without feedback and Civilian subjects with feedback still made significantly more assessment errors upon awakening from the nap than prior to the nap. Finally, subjective ratings of accuracy and the number of targets processed clearly showed that half of the subjects were not aware of significant performance impairments upon awakening from the nap. Even the presence of feedback did not improve their subjective ratings of accuracy and number of targets processed immediately upon awakening. In conclusion, upon awakening from an recuperative nap, and in the presence or absence of external feedback, both accuracy and speed of performance is impaired by sleep inertia and only half of the subjects were able to correctly predict these performance impairments.

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INTRODUCTION

Many services and occupations require individuals to perform and be attentive at any time of the day or night (e.g., healthcare, manufacturing, safety, transportation, and military personnel). Humans are physiologically programmed for a 24-hr schedule with sleep occurring mostly at night and wakefulness mostly during the day (Dinges, 1989). Twenty-four hour operations can create sleep and circadian disruptions that reduce an individual's ability to perform tasks, to judge situations effectively, and to make appropriate decisions (for a review, see Dinges, 1995). Strategic napping is a useful strategy for preventing or reversing the detrimental effects of sleep loss on performance, productivity, and safety in the workplace (Schweitzer et al., 1992; Rosekind et al., 1996; Sallinen et al., 1998; Matsumoto and Harada, 1994; Wyatt and Bootzin, 1994).

One of the main limitations of using naps in operational environments is sleep inertia (Muzet et al., 1995; Rosekind et al., 1995). Sleep inertia refers to the initial period of disorientation and impaired performance experienced immediately upon awakening, and which dissipates gradually with continued wakefulness. In certain operational situations, napping individuals might be awakened and required to work while still in a state of sleep inertia.

To date, the literature studying sleep inertia has focused on the individual level (Ferrara & De Gennaro, 2000). However, decision making is rarely an individual matter. For the most part, decision making involves a process of timely and accurate information being provided by subordinates to a leader, who then is responsible for the ultimate decision (Hollenbeck et al., 1995). To our knowledge there has been no study evaluating cognitive performance impairments induced by sleep inertia in hierarchical teams.

If individuals are to be permitted to recuperate from the effects of sleep deprivation by taking naps in operational environments, we believe it is of interest to investigate if cognitive performance impairments induced by sleep inertia upon awakening affects decision making in teams. This report investigates the occurrence of sleep inertia effects in individuals and teams working on equivalent tasks. A second objective was to look at the impact of sleep inertia on team performance in the presence or absence of feedback. Finally, a third objective was to examine differences between military and civilian teams.

METHODS

Subjects

Sixty four subjects (mean age = 21.7 s.d. 3.0) participated in the study. Subjects were grouped in teams of 4. Eight teams were military (24 males and 8 females) and 8 were civilian (17 males and 15 females). Participants were required to be healthy, and have no history of sleep disturbances, and have normal or corrected to normal vision. Subjects were asked to refrain from alcohol consumption 36 hours prior to commencing the study. Finally, subjects were notified that caffeine and nicotine substances would not be permitted during the study.

Apparatus

Electrophysiological data was collected with ambulatory recorders (Embla from Flaga hf) for the entire duration of the experiment. Somnologica software (Flaga hf) was used on a PC computer to analyze electrophysiological signals. Subjects worked in four experimental rooms of the DCIEM (Defence and Civil Institute of Environmental Medicine) sustained operations laboratory. Rooms are equipped with a table, chair, and Pentium PC computer with color monitor. The subjects slept and napped on a bed provided in the experimental room. Custom computer software was used to administer the cognitive test battery during the experiment[1]. For all tasks, team and individual cognitive performance responses were given by pressing buttons on a PC mouse. Closed-circuit cameras were used to monitor the subjects from a control room.

Procedure

Subjects arrived in the lab at 0800 on Day 1. Following a general introduction to the lab and breakfast, subjects signed informed consent forms for their participation. Subjects were also asked to complete a health, and morningness/eveningness questionnaire. Day 1 was spent practicing the battery of team and individual level cognitive tasks to be performed during the sleep deprivation portion of the experiment starting Day 2 at 0700 and ending Day 3 at 1330 (i.e., 30.5 hrs). All meals and snacks were provided. Task practice concluded at 2200 on Day 1.
Around 1800 of Day 1, subjects were equipped with 9 surface electrodes for continuous ambulatory recording of electroencephalogram (EEG), left and right electrooocculograms (EOG), and submental electromyogram (EMG). The EEG was obtained from the C4-A1, C3-A2, Oz-A1 derivations. The overnight sleep was scheduled between 2230 and 0700. Electroencephalogram (EEG) data was recorded continuously from Day 1 to Day 3. At 1330, following the sleep deprivation period subjects were given a 2 hour opportunity to nap. Upon awakening, subjects performed one last team task session. Following the task session, subjects were debriefed, their electrodes were removed, and they were paid for their participation.

Polysomnography: Electrode placement and sleep scoring (30 sec epochs) was performed according to standardized criteria (Rechtschaffen & Kales, 1968). Time in bed (from lights out to lights on), sleep period time (from falling asleep to lights on), awakenings occurring during sleep (greater than 2 min), total sleep time (sleep period time minus wakefulness), and sleep latency (from lights out to the first stage of sleep), were calculated for each sleep period. Wakefulness and sleep stages (REM sleep, stages 1, 2, 3 and 4) were analysed by measuring total duration and proportion to TST. Latency to slow-wave sleep (SWS) and REM sleep (from sleep onset to the beginning of SWS or REM sleep) were also measured for each sleep episode. Two SWS or REM sleep phases differed when separated by more than 10 min. The number of phases and mean phases duration was calculated for SWS and REM sleep.

Performance tasks: In total, 14 x 2-hour experimental blocks were completed during the sleep deprivation portion of the experiment. Each 2-hour block comprised: a) 25-min

[1] Custom computer software developed by NTT Inc.

team task, b) 25-min individual cognitive task, c) 25-min team task, d) 25-min psychomotor test battery, e) 20-min break. Apart from these experimental blocks, subjects completed two more 25-min team task session (one prior to the nap and one immediately upon awakening from the nap) to study the effects of sleep inertia on team performance. In all these tasks, subjects worked alone in individual rooms; in the team task their computers were networked but no open communication was permitted.

The tasks which were analyzed for this report are now described in more detail:

Team Task: The Team and Individual Threat Assessment Network (TITAN), was used in this experiment to investigate team decision making. TITAN is a simulated naval threat assessment task that can be partitioned between 3 subordinates (nominally Alpha, Bravo, and Charlie) and a team leader, each of whom sees a radar-like screen and a set of menus. The task of the subordinates is to make an assessment of the threat associated with each radar contacts, based on the particular set of information available from their menus (normally five pieces of different information for each subordinates). In a typical trial sequence, the team leader chooses the contact to be processed, the subordinates make their threat assessment individually on their own workstations and these assessments are transmitted to the team leader. The leader makes a final threat assessment, based on the advice given by the subordinates; this "team" threat assessment is submitted to the computer, after which feedback on accuracy was (feedback condition) or wasn't provided (no feedback condition). Finally, a control condition (solo condition) was also included in the experiment in which subjects performed a solo version of the TITAN simulation. This report presents results from TITAN test sessions before and after the nap only.

Psychomotor test battery: This battery involved the following tests: 1) Eyes closed /EEG recording (4-min), 2) Serial Reaction Time (3-min), 3) Logical reasoning (3-min), 4) Subtraction (3-min), 5) Tracking (3-min), 6) Fatigue, sleepiness and mood scales (9-min). From this test battery, only the 4-min eyes closed tests are presented in this report.
Four min eyes closed relaxation period (Pigeau et al., 1987). On their video display terminal, subjects were instructed to relax in a seated position with their eyes closed. At the end of the 4 min the terminal bell rang and subjects were asked to choose from a list of sentences and type in the sentence number best describing how they felt while their eyes were closed.

RESULTS

Morningness/Eveningness and Health Questionnaire

A total of 60 subjects (22 females and 38 males) answered the Morningness/Eveningness (Horne & Östberg, 1976) and a health questionnaire. Results from the morningness/eveningness questionnaire showed that only 1 subject was a moderately morning person, more than half (34) were neither morning or evening persons, 19 were moderately evening, and 6 were definitely evening persons.

The major areas of interest that were included in the health questionnaire were: 1) personal data, 2) the general health of the subject, 3) sleeping behaviours and problems, and 4) consumption of medication, alcohol and caffeinated beverages. Chi-square tests

(Pearson) were used for comparing frequencies in categorical data. Answers pertaining to sleeping behaviours such as sleep timing and duration were lost due to technical difficulties. A summary of the results from the general health questions and personal data can be seen in Table 1. No significant difference was found between males and females or military and civilian subjects regarding general health data.

Table 1: Proportion of males and females reporting positively to specific health factors.

Factors	Male (%)	Female (%)
Smoking	36.8	40.9
Allergies	31.6	40.9
Asthma	2.6	9.0
Operation/injury	23.7	13.6
Unconscious	22.7	34.2
Fainted	45.4	34.2

More than a third of the subjects were smokers. Over one third of the subjects reported some of the more common allergies such as hay fever and three reported being allergic to penicillin. A small proportion of subjects said they were suffering from mild asthma and only one said he require a pump to control it. About 24% of the males and 14% of females had had an operation or a serious injury. The majority said they had been operated for a hernia, appendicitis or because of a bone injury. One subject had a major heart operation at the age of 6 month, and a pacemaker was also inserted.
Most of the subjects reporting being knocked unconscious (23% of the males and 34% of the females) said it happened while playing as kids or participating in a sport (soccer, football, hockey). Almost half of the males and a third of the females said they had fainted once. It was usually due to seeing or giving blood, hypoglycaemia because of skipping meals, or being in the sun too long. Finally none of the subjects said they had epilepsy or seizures.

Around 20% of the subjects reported falling asleep in 5 min or less, approximately 25% took between 10 to 15 min, 35% took 20 to 30 min, and 20% spent 45 min or more to fall asleep. Table 2 summarizes the distribution of subjects reporting sleeping problems and resulting effects. No differences were found between military and civilian and males and females subjects for all sleep behaviour and problems questions with the exception of one question. To the question "How often do you awaken in the morning feeling refreshed?" a greater proportion of males (47%) reported feeling often refreshed whereas only 18% of

the females said so (Chi Square: 8.362, p=0,04). Instead, the majority of females (77%) reported feeling sometimes refreshed when awakening in the morning.

Table 2: Distribution of answers to sleep behaviours and problems questions.

Question	Never (%)	Sometimes (%)	Often (%)	Always (%)
Wake up > 3 times/night	2	47	35	16
Awake more than 30 min	2	58	40	0
Snore	32	42	20	6
Arms and legs kick	22	50	23	5
Talk during sleep	41	42	15	2
Walk during sleep	85	13	2	0
Grind teeth	80	12	5	5
Interrupted breathing during sleep	90	5	5	0
Awaken in good mood	8	30	48	14
Awaken in bad mood	10	75	12	3
Awaken feeling tired	10	62	28	0
Awaken with headache	70	27	3	0

In summary approximately half of the subjects reported frequently waking up more than 3 times a night and 40% said they are often awaken more than 30 min. About 25% of the subjects said they frequently snored and kicked their legs or arms. A little more than 15% said they often talked in their sleep and 10% reported that they often or always grind their teeth. Only 5% of the subjects said they often suffered from interrupted breathing during their sleep. More than half of the subjects report that they often or always awaken in a good mood even though 75% reported sometimes awakening in a bad mood. Finally, almost a third of the subjects reported they often awaken feeling tired and only 3% say they often awaken with a headache.

More than 80% of the subjects reported having almost no difficulty or no difficulty at all to re-establish a sleep routine following a disturbance in their sleep pattern. Only 5% reported that it is extremely difficult for them to get back to their normal sleep schedule.

Only 7 subjects (12%) reported taking medication prior to the study and they were mostly antihistamines to control for their allergies symptoms. Less than 10% mentioned having used sleeping pills in the past but not prior to the study. Half of the subjects consumed up to 3 caffeinated beverages per day and only 1% drank more. Only the alcohol

consumption showed a significant difference (Chi square: 16,0, p=0,0003) between males and females. All females drank less than 5 drinks per week whereas 42% of the males reported drinking more than 7 drinks per week.

Polysomnography

Data from the overnight sleep period of 2 military subjects (1 male) and 11 civilian subjects (6 males and 5 females), and data from the nap sleep period of 17 civilian subjects (8 males and 9 females) were lost due to technical problems. A quick look at the data permitted to notice that even though all subjects were supposed to be in bed by 2230 for the overnight sleep period, military subjects were always in bed later than their civilian counterpart.

Unpaired Student t-tests were used to compare sleep variables between military and civilian subjects for the overnight and nap sleep period. The level of significance was fixed at 5%.

Overnight sleep period

Civilian subjects spent significantly more time in bed (476,9 ± 13,0 min) than military subjects (447,5 ± 8,7 min). Since all subjects were awaken at 0700, this extra time in bed was due to the fact that civilian subjects were always in bed between 20 to 30 minutes earlier than military subjects. As a result they had a significantly longer sleep period (461,6 ± 21,7 vs 433,4 ± 12,4 min) and total sleep time (439,0 ± 23,0 vs 423,1 ± 14,8 min. This extra time in bed also resulted in significantly more time spent in absolute (civilian: 22,5 ± 16,6 min; military: 10,3 ± 8,3 min) and relative wakefulness (civilian: 4,8 ± 3.5 %; military: 2,4 ± 1,9 %). Consequently, military subjects had a significantly greater sleep efficiency in comparison to civilian subjects (94,6 ± 3,0 % vs 92,1 ± 4,2 %). On the other hand, military subjects spent relatively more time moving (MT as a % of TST) than civilian subjects (1,2 ± 0,6 % vs 0,9 ± 0,5 %). No other sleep stage comparisons (1, 2, 3, 4 and REM sleep) between civilian and military subjects reached significance (Table 3).

Nap sleep period

Time in bed, sleep period time, total sleep time, sleep efficiency and sleep latency were similar in military and civilian subjects, as were the duration and percentage of sleep stages 1, 2, SWS, and REM sleep (Table 4). Military subjects had significantly more arousals than civilian subjects (8,8 ± 6,5 vs 4,8 ± 3,8). However, this larger number of arousals did not result in more stage changes or time spent awake. On the contrary, civilian subjects were found to spend more absolute and relative time in wakefulness than military subjects (2,3 ± 2,7 min vs 0,8 ± 1,6min; 2,0 ± 2,3 % vs 0,7 ± 1,4 %).

Table 3. Overnight sleep characteristics of civilian (n = 21) and military (n = 31) subjects. All mean values are given with one standard deviation (s.d.).

		Civilian		Military		P value
			s.d.		s.d.	
In minutes	Time in bed (TIB)	476,9	13,0	447,5	8,7	0,0001
	Sleep period time (SPT)	461,6	21,7	433,4	12,4	0,0001
	Total sleep time (TST)	439,0	23,0	423,1	14,8	0,0040
	Slee efficiency (TST/SPT)	92,1	4,2	94,6	3,0	0,0166
	Sleep latency	15,4	14,0	14,1	10,8	ns
	Wakefulness	22,5	16,6	10,3	8,2	0,0010
	Stage 1	16,2	8,1	13,7	7,1	ns
	Stage 2	203,1	30,9	201,4	25,2	ns
	Stage 3	37,6	10,4	36,1	14,1	ns
	Stage 4	91,1	28,8	84,3	22,8	ns
	Slow-wave sleep (SWS)	128,8	31,0	120,5	25,5	ns
	REM sleep	87,0	25,3	82,4	21,5	ns
	Movement time (MT)	3,8	2,2	5,1	2,6	ns
	SWS latency	14,0	5,6	14,7	7,0	ns
	REM latency	112,3	53,8	95,8	37,2	ns
	Mean REM sleep phases duration (min)	25,1	7,8	24,0	6,6	ns
	Mean SWS phases duration (min)	37,4	20,2	35,6	11,1	ns
Relative	Wake (%SPT)	4,8	3,5	2,4	1,9	0,0269
	Stage 1 (%TST)	3,7	1,9	3,3	1,8	ns
	Stage 2 (%TST)	46,2	6,3	47,6	6,1	ns
	Stage 3 (%TST)	8,6	2,3	8,5	3,4	ns
	Stage 4 (%TST)	20,8	6,6	19,9	5,3	ns
	SWS (%TST)	29,4	7,0	28,5	5,9	ns
	REM (%TST)	19,7	5,4	19,4	4,8	ns
	MT (%TST)	0,9	0,5	1,2	0,6	0,0436
Absolute	REM phases	3,8	0,8	3,8	0,7	ns
	SWS phases	3,8	1,5	4,5	1,4	ns
	Awakenings (>2 min)	5,5	4,0	3,6	3,7	ns
	Arousals (≥3 sec)	35,6	17,1	43,4	24,2	ns
	Stage changes	125,6	30,6	115,7	29,3	ns

Table 4. Nap sleep characteristics of civilian (n = 15) and military (n = 32) subjects. All mean values are given with one standard deviation (s.d.).

		Civilian		*Military*		**P value**
			s.d.		s.d.	
In minutes	Time in bed (TIB)	119,9	3,8	120,6	2,3	ns
	Sleep period time (SPT)	116,6	5,4	114,3	7,7	ns
	Total sleep time (TST)	114,3	5,8	113,5	7,8	ns
	Slee efficiency (TST/SPT)	95,3	2,9	94,1	5,9	ns
	Sleep latency	3,3	2,3	6,3	7,0	ns
	Wakefulness	2,3	2,7	0,8	1,6	0,02
	Stage 1	2,5	1,3	2,9	2,1	ns
	Stage 2	28,2	6,9	30,0	10,8	ns
	Stage 3	11,4	9,2	9,0	4,0	ns
	Stage 4	57,5	13,9	54,9	14,1	ns
	Slow-wave sleep (SWS)	68,9	13,1	63,9	16,1	ns
	REM sleep	13,8	10,7	15,8	14,2	ns
	Movement time (MT)	0,9	0,9	0,9	0,8	ns
	SWS latency	7,2	3,4	7,5	3,4	ns
	REM latency	71,4	15,5	65,8	10,8	ns
	Mean REM sleep phases duration (min)	17,3	11,6	20,1	15,1	ns
	Mean SWS phases duration (min)	50,2	23,5	45,1	16,6	ns
Relative	Wake (%SPT)	2,0	2,3	0,7	1,4	0,03
	Stage 1 (%TST)	2,2	1,2	2,6	2,0	ns
	Stage 2 (%TST)	24,8	6,5	26,5	9,5	ns
	Stage 3 (%TST)	10,0	7,9	8,0	3,6	ns
	Stage 4 (%TST)	50,1	10,9	48,1	11,4	ns
	SWS (%TST)	60,1	10,0	56,1	13,1	ns
	REM (%TST)	12,1	9,5	14,0	12,8	ns
	MT (%TST)	0,8	0,8	0,8	0,7	ns
Absolute	Stage at awakening	3,5	1,2	3,3	1,1	ns
	REM phases	1,0	0,0	1,0	0,0	ns
	SWS phases	1,7	0,5	1,7	0,5	ns
	Awakenings (>2 min)	0,7	0,6	0,3	0,7	ns
	Arousals (≥3 sec)	4,8	3,8	8,8	6,5	0,03
	Stage changes	29,7	14,0	24,2	7,9	ns

Table 5 shows the number of military or civilian subjects that were awakened from the afternoon nap in stage 2, SWS and REM sleep. Most of the awakenings occurred in SWS

(46,7% of civilian, 56,2% of military), followed by stage 2 (29,4 % of civilian, 34,4 % of military), and REM sleep (17,6 % of civilian, 0,09 % of military).

Table 5. Number of military and civilian subjects that were awakened from the afternoon nap in stage 2, SWS, and REM sleep.

Stage at awakening	Military	Civilian
Stage 2	11	3
SWS	18	7
REM sleep	3	5

Finally, possible effect of gender on sleep variables was looked at within each type of subjects (military and civilian). No significant effect of gender on sleep variables were found for the overnight and nap sleep period.

Four minutes eyes closed test

Four minutes eyes closed trials occurred approximately every 2 hours starting on Day 2 at 0940 hour after an overnight sleep in the laboratory. A total of 14 trials were delivered before the nap scheduled at 1330 hour on Day 3. Wakefulness and sleep stages were scored for the entire duration of each trial in 30-sec epochs according to standardized procedures (Rechtschaffen & Kales, 1968). In order to compare the results from the subjects' self-assessment of fatigue and their EEG evaluation, the total number of minutes of sleep (all stages) was also calculated for each subject and trial (figure 1). From the sixty-four subjects who participated in the study. EEG data from the eyes closed trials of 8 subjects were lost due to technical problems.

Total sleep and self-assessments of sleepiness dependent variables were analysed using a series of ANOVAs in which status (Military or Civilian), and gender (Male and Female) were between-subjects factors and Trial was a repeated factor. The level of significance was set at 0,05. Following ANOVAs, post hoc comparisons were conducted. It was hypothesized that mean levels for the dependent variables would show a significant increase in the total amount of sleep and self-assessment of sleepiness as sleep loss increased.

There was a significant Trial effect on Total sleep ($F=22,7$, $p<0,0001$) and Self-assessment ($F=19,0$, $p<0,0001$) but no other effects or interactions. The time spent asleep after 05h00 was significantly greater than the ones prior to 05h00 whereas the time spent asleep after the 01h40 and 03h40 trial was significantly different from all trials done before midnight with the exception of the 13h40 trial. Between midnight and 05h00 subjects spent approximately up to half of the trial asleep (2 minutes). After 22 hours of

wakefulness (after 05h00), subjects fell asleep very quickly and slept on average for more than 3 minutes out of 4.
Self-assessment showed a similar pattern, self-assessment given after 05h00 showed significantly more sleepiness than the ones given after 18h00 and the 11h40 trial. Self-assessment given between midnight and 05h00 were also significantly different from the 11h40 trial and the ones given after 18h00.

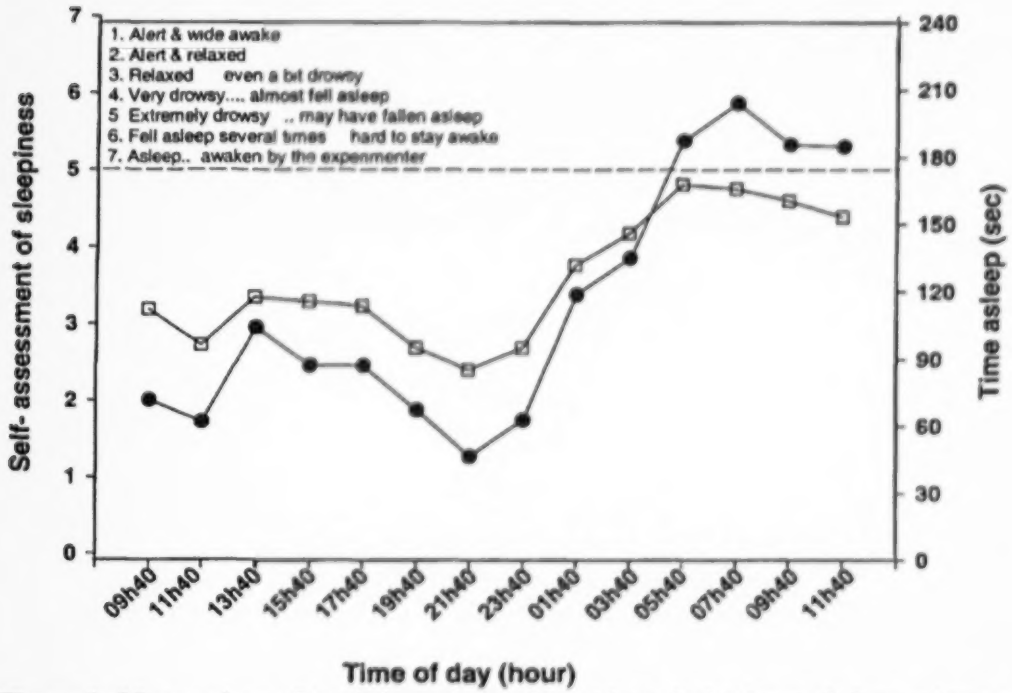

Figure 1: Mean values of total time spent asleep (close circle) for each four minutes eyes closed trials and self-assessment of sleepiness (open square) given immediately after each trial as a function of time of day. (N=56)

A visual comparison of the two curves in figure 1 shows that self-assessment made by the subjects are generally following the fluctuations seen in the objective evaluation of sleepiness given by the time asleep. When subjects slept more after midnight they gave a higher self-assessment of their sleepiness and when they slept less around 21h00 they gave a lower assessment. However, when looking more closely at the self-assessments, the means are always less than 5 and a rating of 5 means that they felt extremely drowsy and they may have fallen asleep.

Performance and subjective assessments

Performance and subjective assessments dependent variables were analysed using a series of ANOVAs in which status (Military or Civilian), social condition (Individual and Team), and condition (Feedback and NO Feedback) were between-subjects factors and

prepost (before and after the nap) was a repeated factor. Given that sleep inertia effects dissipate over time, similar analyses were performed on a shorter period of time (first 6 min) to determine whether some sleep inertia effects could only be evident at the beginning of the session. The level of significance was set at 0.05. Following ANOVAs, planned comparisons were conducted. Planned comparisons focused on statistical tests comparing values before and after the nap. It was hypothesized that mean levels for the dependent variables would show a significant decline upon awakening from the nap.

Team Titan Performance

Seven Teams (3 Civilian and 4 Military) performed Titan sessions with feedback before and after the nap and six teams (4 Civilian, 2 Military) performed sessions without feedback. Eight military subjects did Individual Titan sessions with feedback prior and after the nap.

The Titan program for each target processed during a session automatically generated Target processing time, assessed threat, and correct threat levels. The percentage of assessment error for each target processed was calculated by subtracting the assessed threat from the correct threat. The total number of target processed was calculated for the first 6 min of a Titan session and for the entire duration of a session (24 min).

Leader results

Analysis of Leader's target processing times showed a significant interaction effect between status and condition ($F=4,9$, $p<0.03$). Military Leaders when given performance feedback took longer to process targets whereas Civilian Leaders took less time than without feedback. No other comparisons reached significance. A similar analysis was performed with the assessment error (%) and a significant prepost effect was found ($F=8,8$, $p<0,003$). Team leaders made more assessment errors upon awakening from the nap (4,8%) than prior to the nap (3,7%).

When the first 6 min were analysed a significant interactions between status and condition ($F=7,4$, $p<0,008$) and between status and prepost ($F=5,5$, $p<0,02$) were found. As for the entire session results, Military Leaders slowed down when given feedback whereas Civilian Leaders took less time to process the targets. Moreover, target-processing time upon awakening from the nap was slower than prior to the nap especially for Military Leaders. For the first 6 min a significant interaction effect was found for the assessment error (%) between status, condition, and prepost ($F=4,7$, $p<0,03$). This interaction was not significant in the 24 min analysis. Planned comparisons showed that Military Leaders without feedback and Civilian Leaders with feedback made more than twice as much assessment errors upon awakening than prior to the nap. Civilian Leaders assessment error was not significantly reduced upon awakening when performing without feedback.

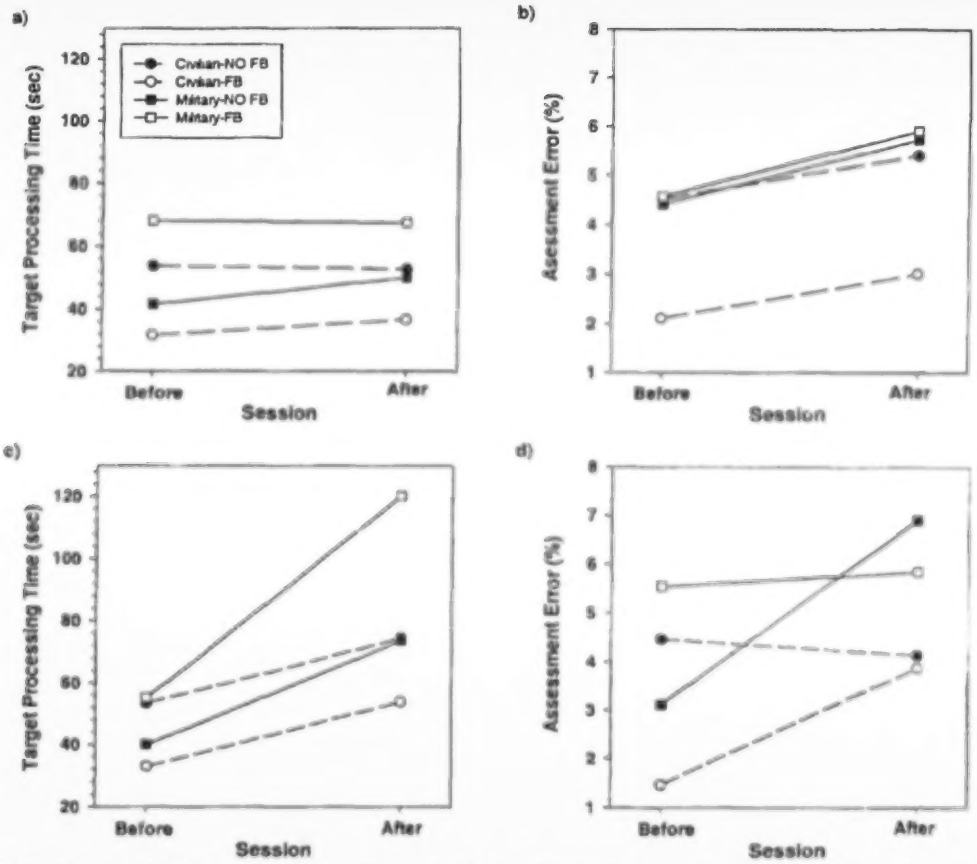

Figure 2: Leader processing time and assessment error as a function of session before and after the nap. Graphs a) and b) represent mean values for the entire 24 min session and graphs c) and d) represent mean values for the first 6 min of the session.

Subordinate results

There was a significant prepost effect on target processing time (F=20,5, p<0,0001) but no other effects or interactions. Subordinates processed the targets slower upon awakening from the nap in comparison to prior to the nap. No significant effects were found with the percentage of assessment errors.

When only the first 6 min were analysed a similar prepost effect was found for target processing time (F=29,5, p<0,0001). However, significant effects of prepost (F=5,0, p<0,03) and interaction between status and condition (F=4,0, p<0,05) were found for the percentage of assessment error. During the first 6 min of the session performed upon awakening, all subordinates made significantly more errors. However, Civilian subordinates made fewer errors with feedback whereas Military subordinates made more errors when given feedback.

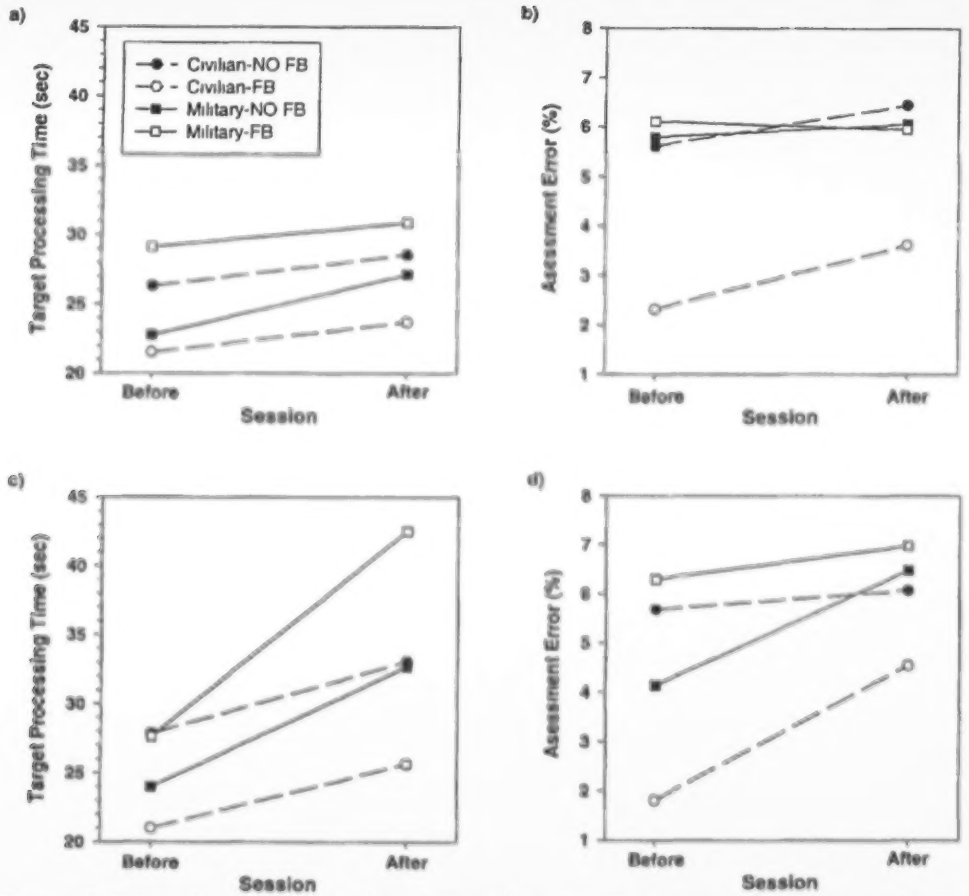

Figure 3: Subordinates processing time and assessment error as a function of session before and after the nap. Graphs a) and b) represent mean values for the entire 24 min session and graphs c) and d) represent mean values for the first 6 min of the session.

Number of targets processed

When the number of targets processed during the session was looked at, there was a significant interaction between condition, status and prepost ($F=6,0$, $p<0,04$). Military teams processed more targets without feedback than with feedback. In contrast, planned comparisons showed that Civilian teams processed more targets with feedback and the number of targets processed dropped significantly upon awakening. When Civilian teams performed without feedback, the number of targets processed upon awakening in comparison to prior to the nap was not significantly affected.

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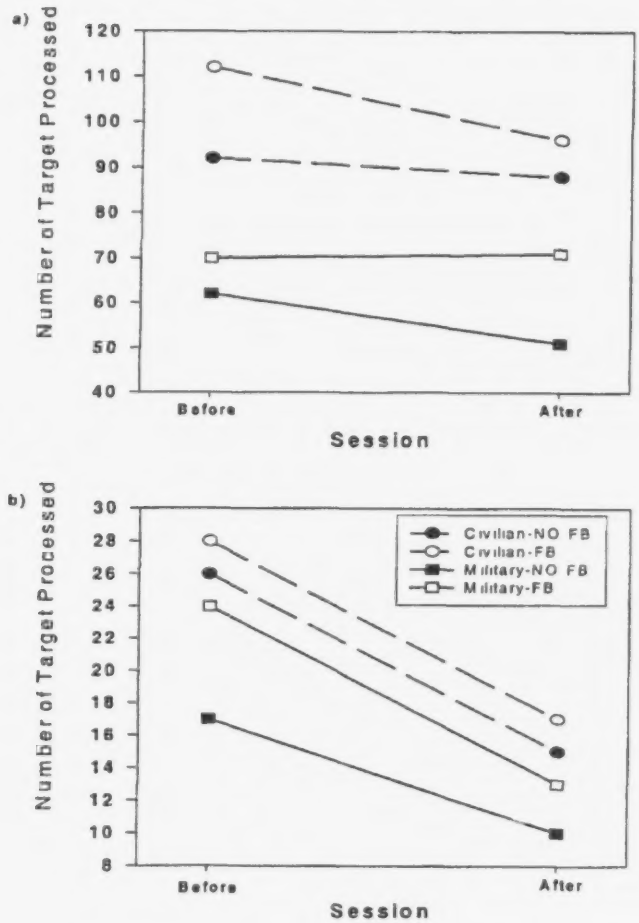

Figure 4: Number of targets processed as a function of session before and after the nap. Graph a) represents mean values for the entire 24 min session and graph b) represents mean values for the first 6 min of the session.

Different results were obtained when the first 6 min were analysed. The analysis revealed a significant effect of prepost (F=40,6, p<0,0004) and a significant interaction between status and condition (F=6,4, p<0,04). Both Civilian and Military teams processed less targets in the first 6 min upon awakening than prior to the nap. Civilian teams processed more targets with feedback whereas Military teams processed more targets without feedback.

Individual Titan performance

Individual Titan results showed significant prepost effects for target processing times (F=73,7, p<0,0001) and the number of targets processed (F=39,1, p<0,0001) but there was no significant interaction effects. Subjects processed at a significantly slower pace upon awakening from the nap resulting in significantly less targets processed.

Comparison between Individual Titan and Team Titan showed a significant interaction effect of social condition and prepost for target processing time (F=15,9, p<0,0001) and the number of targets processed (F=47,6, p<0,0001). Thus, Individual target processing time was significantly slower upon awakening and resulted in less targets processed whereas Team performance was not significantly affected.

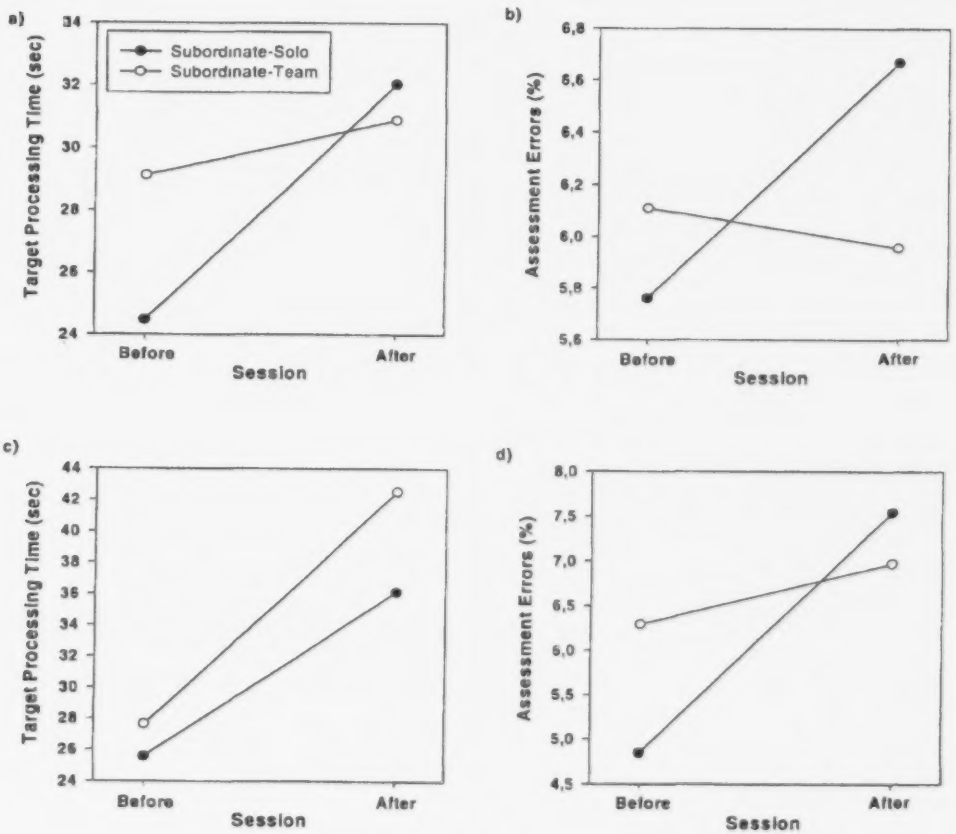

Figure 5: Solo and Team processing time and assessment error as a function of session before and after the nap. Graphs a) and b) represent mean values for the entire 24 min session and graphs c) and d) represent mean values for the the first 6 min of the session.

When only the first 6 min were analysed, prepost effects were found for target processing time (F=50,6, p<0,0001), the percentage of assessment errors (F=3,8, p<0,05) and the number of target processed (F=74,5, p<0,0001). Individuals and Teams performance was worse upon awakening from the nap. There was also a significant effect of social condition (F=55,5, p<0,0001) for the number of target processed. Teams processed significantly less targets than individuals.

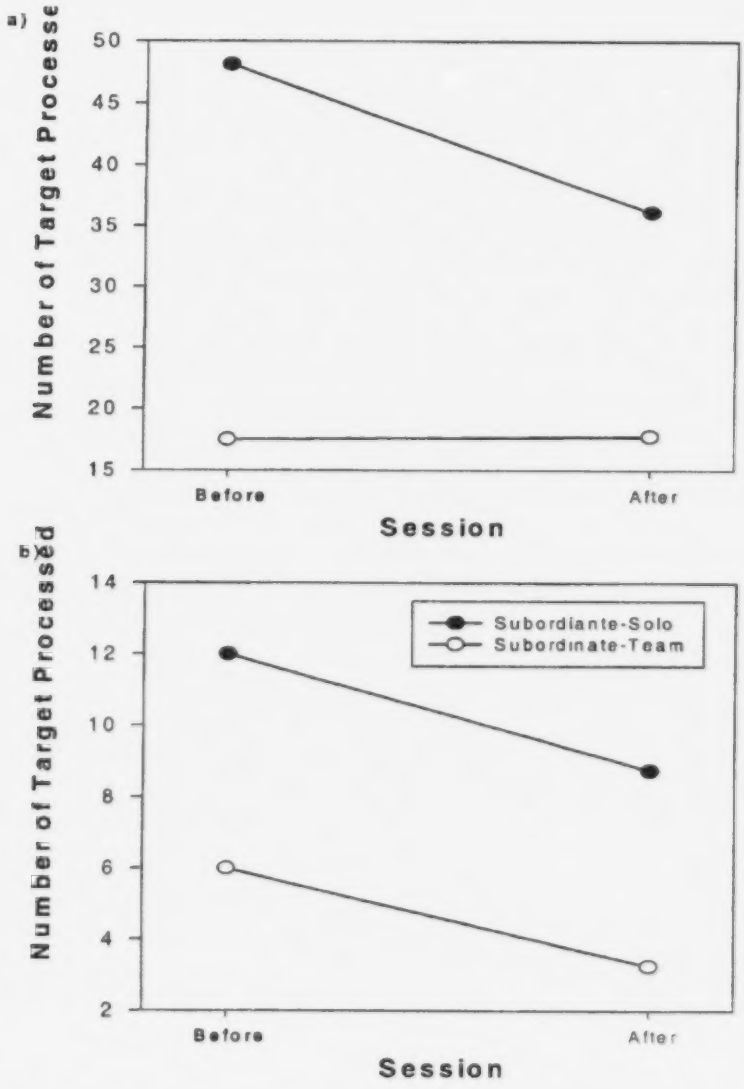

Figure 6: Number of targets as a function of session before and after the nap. Graphs a) and b) represent mean values for the entire 24 min session and graphs c) and d) represent mean values for the the first 6 min of the session.

Subjective Assessments

Performance ratings

Subjective ratings of accuracy and performance (number of target processed) were subjected to ANOVA analysis. No significant effect of status, condition, and interaction were found for accuracy ratings. As for the self-ratings on the number of targets processed, again no significant effects were found. However, Military subjects had a tendency to be slightly more optimistic than Civilian subjects ($p<0,06$) in their subjective ratings of accuracy and performance. The majority of the subjects rated their accuracy to be similar (15%) or better (50%) upon awakening from the nap. Only 35% of the subjects thought their accuracy was worse after than prior to the nap. Subjective ratings of the number of target processed showed similar results. A little more than half of the subjects thought they processed the same number (15%) or more targets (42%) upon awakening than prior to the nap whereas 43% thought they processed fewer targets after than prior to the nap.

Nap ratings

The majority of the subjects (70 %) said they had no problem falling asleep during the nap, 24% had slight trouble falling asleep and only 6% had moderate to considerable trouble falling asleep. On average subjects answered that they took 7 min (s.d.=6,4) to fall sleep. More than half (59%) reported taking 5 min or less to fall asleep, 28% said they took between 5 and 10 min and 14% responded that they took more than 10 min. Only, 16% of the subjects reported waking up once during the nap and 5% said they woke up more than once. Most subjects (79%) said they did not wake up during the nap. Sleep quality ratings being below average were reported by 16% of the subjects. The majority reported having a good (70%) or average (14%) sleep quality. A little more than half of the subjects (58%) thought they slept for 1,5 hours or less, 21% reported that they slept for 2 hours, and 21% thought that they slept between 2,5 and 3 hours. Finally, most subjects (88%) answered being asleep when the experimenter entered the room to wake them up.

DISCUSSION

Health and Mornigness/Eveningness Questionnnaire.

Despite the fact that subjects were sleeping in an unfamiliar environment and with electrodes attached they slept better than their every day estimation of their sleep at home. Most of the subjects (60%) reported that they normally fell asleep within 10 to 30 minutes. Results from the overnight sleep periods showed that 80% of the subject took 10 to 20 min to fall asleep. Approximately 40% of the subjects reported being often awakened more than 30 min at night, a value that was not reflected in the overnight sleep results with only 5% of the total awakenings being longer than 2 min. These differences may be explained by either a tendency by the subjects to underestimate their sleep quality and duration at home and by overestimating the duration of their awakenings periods, and time they take to fall asleep (Baker et al., 1999) or by really not having good consolidated sleep at home due to poor sleep hygiene. For instance, 42 % of male subjects reported drinking more than one alcoholic beverages per day. Some sleep disturbances mentioned by the subjects may be explained by the fact that alcohol will create sleep maintenance

difficulties (Zarcone, 1989). On the other hand, caffeine consumption was not excessive with half the subjects reporting drinking up to 3 caffeinated beverages per day. Interestingly, even though no significant differences were found between males and females sleep variables for the overnight period, most female subjects reported feeling sometimes refreshed upon awakening in the morning whereas males reported feeling often refreshed. This perception difference between male and female found in this study cannot be used to affirm a gender difference in self-estimation of sleep quality. Further studies are needed to clarify this issue. The majority of the subjects did not report any sleep problems.

Finally the Morningness/Eveningness results were typical of a healthy young group of subjects with half of them being neither morning or evening types and the other half being either moderately evening or definitely evening types (Gander et al., 1993).

Sleep composition

Subjects exposure to the new environment and recording conditions without any prior adaptation night did not affect negatively their overnight sleep composition which fell within the normal ranges reported in the literature for their age group (Carskadon & Dement, 1989). The normal sleep variables for young adults expressed as a percentage of total sleep time consist of 2 to 3 % wakefulness, 45 to 60 % stage 1+2, 15 to 30 % SWS, and 20 to 35 % of REM sleep (Carskadon & Dement, 1989). Subjects fell asleep within 15 to 20 min and sleep efficiencies were greater than 90%. We than can conclude that on average subjects started their sleep deprivation period after a normal night sleep. Although civilian subjects spent 20 to 30 min more time in bed, only half of this extra time was spent asleep. On the other hand, military subjects slept more efficiently and spent significantly less time in wakefulness. As a result, no other sleep stages showed any significant differences between civilian and military subjects.

As expected, prior sleep loss, the duration of the afternoon nap (120 min) and its circadian placement (1330) resulted in large amount of SWS (55%), short sleep latencies (7 min or less), and high sleep efficiencies (94%). Consequently, military and civilian subjects were mostly awaken from SWS, followed by stage 2 and REM sleep. Moreover, the increased sleep depth (in terms of amount of SWS and sleep stage at awakening) caused by sleep deprivation and time of day resulted in sleep inertia effects upon awakening (see below). Subjects' self evaluation of sleep quality and time to fall asleep was quite good. However, 58% thought they slept for 1.5 hours or less when they actually slept for 2 hours. It is possible that subjects being far from completely rested when awakened, add the impression of not having slept enough and it may have affected downward their evaluation on how long they had slept.

Objective measures of sleep deprivation

Objective measurement of sleepiness trough the 4 min eyes closed task showed that subjects had difficulty resisting sleep and spent more than 3 min asleep after 17 hours of wakefulness. Self-evaluation of their sleepiness showed similar patterns with higher values after 22 hours of sleep loss. Nevertheless, subjects rarely assessed their sleepiness as falling asleep several times or being asleep and having been awaken by the experimenter. Either the subjects couldn't evaluate if they were asleep for a few minutes or they did not want to admit it. For the most part subjects probably did not know they were asleep. It has been shown that healthy individuals almost always report being awake

when awaken from stage 1, and about half of the time when awaken from the sleep onset of stage 2 (Agnew & Webb; 1976, Coates et al., 1983). Time spent asleep was indeed mostly stage 1 and 2.

Sleep inertia effects

Analyses of Titan performance showed that whether subjects were performing in teams or individually they suffered from significant sleep inertia impairments immediately upon awakening from the nap.

Team performance decrements due to sleep inertia were seen in the mean assessment errors for leaders and in the mean target processing time of subordinates for the entire duration of a session (24 min). This is consistent with the findings of Bruck and Pisani (1999) showing that sleep inertia reduced decision-making performance for at least 30 min. When only the first 6 min of the session were examined, both the assessment errors and target processing times were significantly impaired upon awakening for leaders and subordinates. Individual performance also showed significant decrements immediately upon awakening for target processing times, assessment errors, and the number of targets processed for the entire duration of the session and for the first 6 min.

Sleep inertia had more impact on performance of individuals than teams. Consequently, individual target processing time was significantly slower upon awakening and resulted in less targets processed whereas Team performance was not significantly affected over the entire 24 min session. This difference was not present in the first 6 min of the session where both individual and team processing times and number of targets processed were impaired by sleep inertia. Essentially, teams were able to improve their performance with time awake whereas individual performance was still affected by sleep inertia by the end of the 24 min session. Horne (1988) suggested that performance deficits can be overridden by the input of motivational or attentional resources. It is conceivable that individuals lacked the motivation to wake up and improve their performance or that each subordinate, at the team level, may have had an additional motivation to try to wake up quickly since the leader was counting on their answer to make his final assessment. The team environment somehow speeded up the recovery and resulted in social facilitation. Specific evaluation of the impact of motivation on sleep inertia effects needs to be investigated.

When looking at the impact of feedback on performance, the results showed that Military and Civilian leader were affected differently. Interestingly, Civilian leaders processed targets significantly faster with feedback than with no feedback whereas Military leaders took more time to process targets when given feedback. Nevertheless, leaders processing time in the presence or absence of feedback was still significantly increased immediately upon awakening, and more so for Military leaders in the first 6 min of a session. Even though all leaders took longer to processed targets immediately upon awakening because of sleep inertia effects, Military leaders without feedback and Civilian leaders with feedback still made significantly more assessment errors upon awakening from the nap than prior to the nap.

Similar sleep inertia effects were seen in subordinates as they processed targets slower immediately upon awakening from the nap. In contrast to Military subordinates, Civilians processed more targets with feedback than without feedback. On the other hand, the number of targets processed upon awakening was not significantly affected by sleep inertia in Civilian subordinates working with no feedback when looking at the entire 24

min session. In contrast, during the first 6 min of the sessions performed all subordinates made significantly more assessment errors upon awakening. However, Civilian subordinates made fewer errors with feedback than Military.
It is difficult to understand why Civilian leaders and subordinates worked faster with feedback than without feedback. It is possible that Civilian subjects took more time processing targets without feedback because they were processing information more cautiously whereas Military subjects took more time interpreting feedback information. Even under sleep inertia effects, Civilian subjects were able to take advantage of the feedback given by successfully using the information to reduce their assessment errors and still increase their number of target processed in comparison with sessions without feedback. Interestingly, even though this performance task was self-paced both speed and accuracy were significantly affected by sleep inertia. Previous studies had shown that low level of brain arousal on awakening had a negative impact on both speed and accuracy (Balkin & Badia, 1988; Naitoh et al., 1993) but recent evidence showed that sleep inertia affected more specifically performance accuracy (Ferrara & de Gennaro, 2000). In the no-feedback situation, subjects may not have been sufficiently aware of their drop in performance upon awakening to slow down sufficiently and try to improve their accuracy. On the other hand, subjects who were given feedback had information to better evaluate the impact of sleep inertia on their performance accuracy and try to compensate for its effect by either slowing down or trying to improve their performance. Apparently, even when subjects are given feedback they are not able to compensate for the negative effects of sleep inertia on their performance.

Finally, subjective ratings of accuracy clearly showed that the majority of subjects (65%) were not aware of a significant increase in assessment errors upon awakening from the nap. Subjective ratings of the number of target processed showed similar results. Only 43% of the subjects thought they processed less targets upon awakening than prior to the nap. Even the presence of feedback did not improve their subjective ratings of accuracy and number of target processed immediately upon awakening. Dorian et al. (2000) suggested that, in situations of sleep loss and fatigue, self-monitoring of actual performance may provide an accurate indication of the level of performance impairment. In contrast, the findings of the present study do not support self-monitoring as an effective mechanism to estimate performance impairment caused by sleep inertia.

Conclusions

Although the results of this study need to be replicated, a few conclusions can be made. Even though objective and subjective measures of sleepiness showed substantial sleep deprivation effect prior to the nap, subjects were not able to recognize the extent of their sleepiness. It could be interesting to study if a better awareness of sleepiness can be taught. This study was able to document that complex cognitive tasks such as TITAN are affected by sleep inertia whether they are performed individually or in teams. Decision-making performance decrements caused by sleep inertia are dissipated more rapidly in teams than in individuals. Even though TITAN sessions were self-paced, sleep inertia affected both performance speed and accuracy and half of the subjects were unaware of these effects even when presented with feedback. Thus, the current study indicates that in

situations requiring individuals to perform individually or in teams, the adverse effects of sleep inertia have to be considered in advance.

Future studies should investigate the extent of subjects awareness of sleep inertia effects on performance. A better understanding of subjects awareness of sleep inertia effects (or lack of it) may help future research into finding effective alerting tools to quickly eliminate sleep inertia effects.

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14 ABSTRACT

(U) Sixty four healthy volunteers, aged 20 to 36 years, were grouped in teams of four. Eight teams were military (24 males and 8 females) and 8 were civilian (17 males and 15 females). Fifty six subjects were randomly assigned either to a feedback or no feedback condition and 8 military subjects did a control condition (solo condition). Participants were equipped for continuous ambulatory recording of EEG, EOG and EMG and completed 14 x 2-hour experimental blocks during the sleep deprivation portion of the experiment. Subjects completed two additional 25-min team task sessions (before and after the nap) to study the effects of sleep inertia on team performance. The Team and Individual Threat Assessment Network (TITAN), was used in this experiment to investigate team decision making. A two-hour nap was scheduled between 1330 and 1530 hrs after 30.5 hrs of sleep loss. Titan performance showed that whether subjects were performing in teams or individually they suffered from significant sleep inertia impairments immediately upon awakening from the nap. However, teams were able to improve their performance with time awake whereas individual performance was still affected by sleep inertia by the end of the 24 min session. Finally, even in the presence of feedback, subjective ratings of accuracy and the number of targets processed clearly showed that half of the subjects were not aware of significant performance impairments upon awakening from the nap. In conclusion, upon awakening from an recuperative nap, and in the presence or absence of external feedback, both accuracy and speed of performance is impaired by sleep inertia and only half of the subjects were able to correctly predict these performance impairments.

(U) Soixante-quatre bénévoles en bonne santé, âgés de 20 à 36 ans, ont été groupé en quatre équipes. Huit équipes étaient composées de militaires (24 hommes et 8 femmes) et de civils (17 hommes et 15 femmes). Cinquante-six sujets étaient soumis à une condition rétroactive ou non rétroactive et 8 sujets militaires servaient de condition contrôle (condition seule). Les participants étaient équipés pour effectuer des enregistrements ambulatoires de l'EEG, de l'EOG et de l'EMG et accomplissaient 14 blocks d'essais de deux heures pendant la partie de l'expérience où ils sont privés de sommeil. Ils ont effectué deux séances de travail d'équipe de 25 minutes (avant et après le somme) pour étudier les effets de l'inertie du sommeil sur le rendement d'équipe. On s'est servi du Réseau d'évaluation des menaces pour l'individu ou le groupe (TITAN) dans cette expérience pour analyser la prise de décisions de l'équipe. Un somme de deux heures était prévu entre 13 h 30 et 15 h 30 après 30 heures et demie sans sommeil. Le rendement mesuré par le TITAN a montré que, participant à un groupe ou non, les sujets souffraient d'un affaiblissement marqué de leurs facultés causé par l'inertie du sommeil immédiatement après le somme. Toutefois, les équipes étaient capables d'améliorer leur rendement avec le temps d'éveil alors que les individus avaient leur rendement personnel encore influencé par l'inertie du sommet au bout de la séance de 24 min. Enfin, même en présence de rétroaction, les notations subjectives de la précision et le nombre de cibles traités ont montré clairement que la moitié des sujets n'étaient pas conscients de l'affaiblissement marqué de leur rendement après le somme. En conclusion, immédiatement après un somme de récupération et en présence ou non de rétroaction externe, la précision et la vitesse de rendement sont à la fois affaiblies par l'inertie de sommeil et seulement la moitié des sujets étaient capables de prédire les affaiblissements de rendement correctement.

15 KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) sleep inertia, naps, feedback, sleep deprivation

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